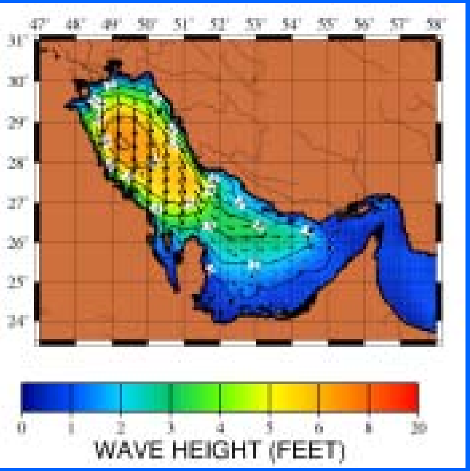
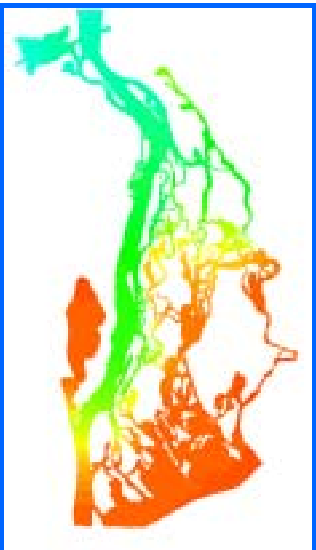
High Fidelity Simulations of Littoral Environments (HFSoLE)

C75





Rick Allard

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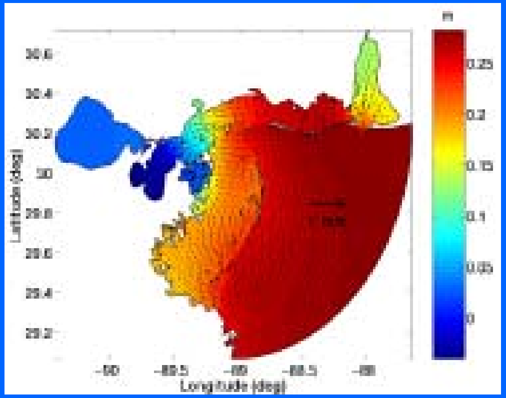


http://www.ocean.nrlssc.navy.mil/hfsole/hfsole.html

Collaborators

- Charlie Barron, Cheryl Ann Blain, Pat Hogan, Tim Keen, Lucy Smedstad, Alan Wallcraft (NRL Stennis Space Ctr, MS)
- Charlie Berger, Stacy Howington, Jane Smith (ERDC)
- Rich Signell (SACLANT)
- Mark Cobb (Sverdrup Technology)
- Matt Bettencourt (USM CHL)

Outline

- Introduction to Portfolio
- Models
  - HYCOM
  - NCOM
  - STWAVE
  - ADH
  - SWAN
- Persian Gulf Simulations (ADCIRC, SWAN, LSOM)
- Adriatic Simulations (COAMPS, NCOM, SWAN)
- MCEL (Model Coupling)
- Future Plans

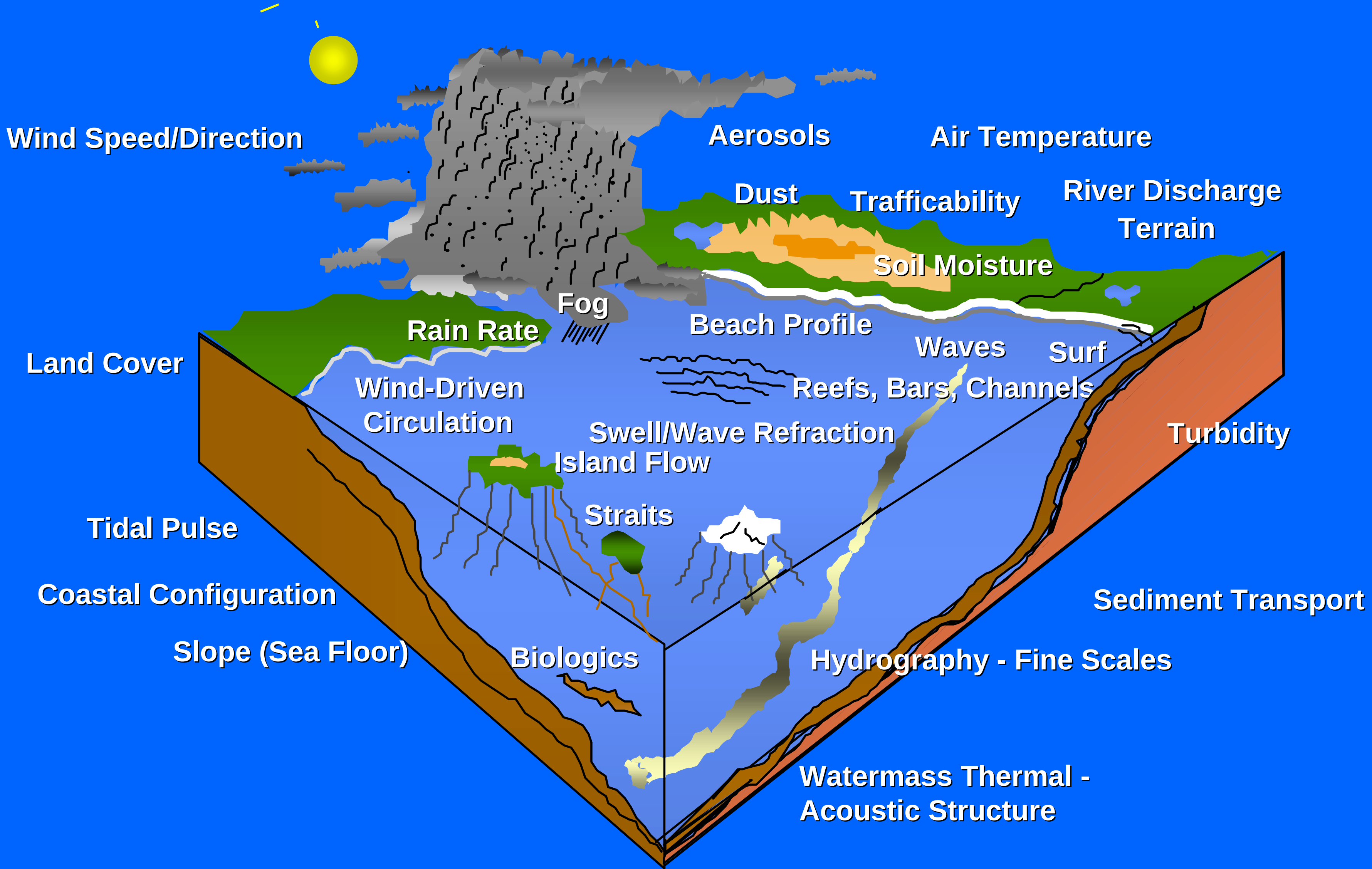
THE IMPORTANCE OF THE LITTORAL...

95% of world's population live within 600 miles of the sea

80% of all countries border the coast

80% of world's capitals lie within 300NM of shore

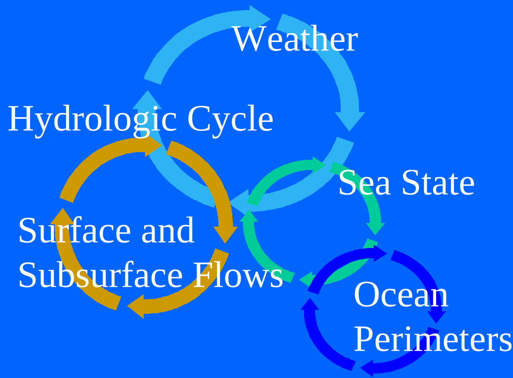
METOC Focus - Littoral Water

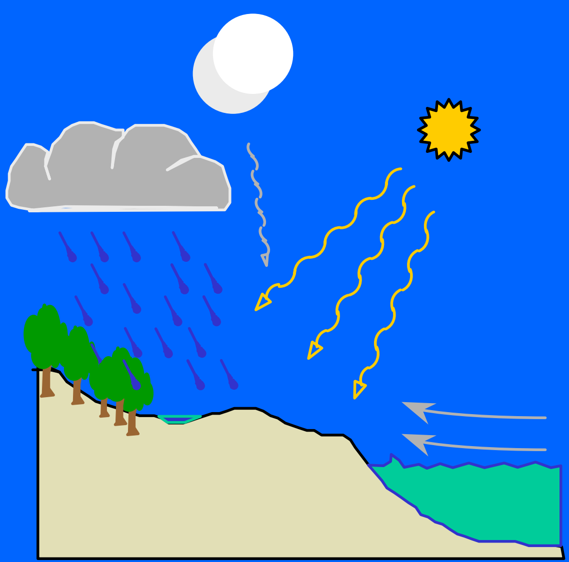


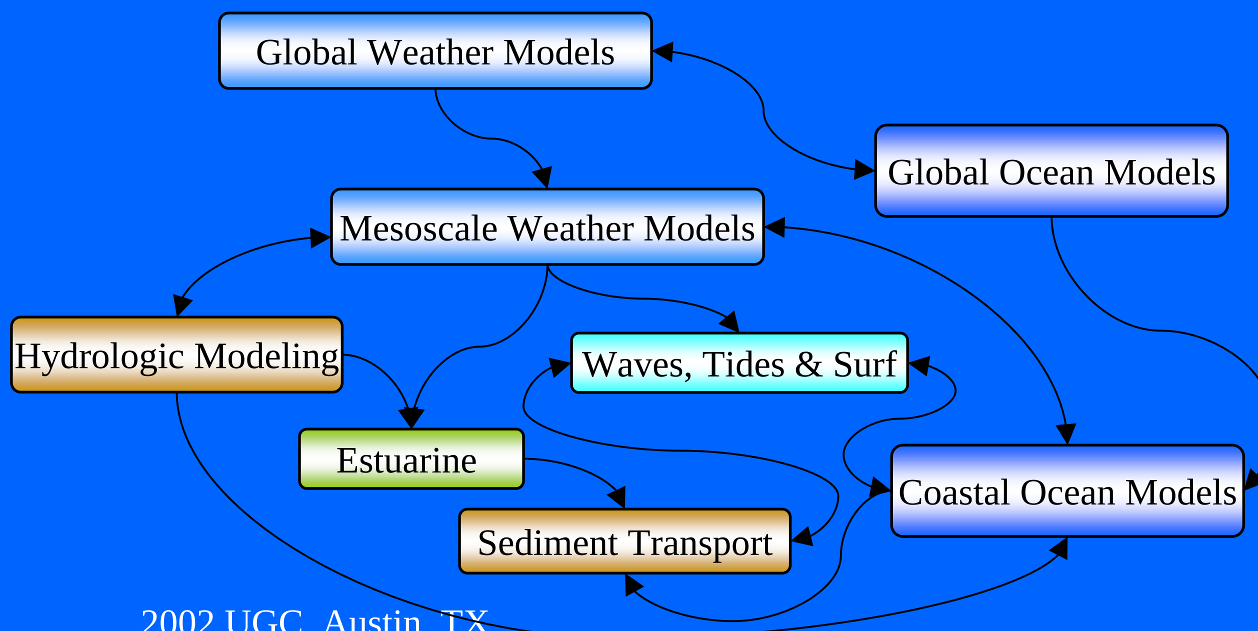
Environmental Processes

Environment

Processes







Structure of Portfolio

HFSOLE
Richard Allard NRL-SSC
Robert Athow ERDC

SLE-1
System Integration & Framework
HYCOM, NCOM Ocean Models
Model Integration

Dr. Alan Wallcraft
Naval Research Laboratory
Stennis Space Center, MS

Dr. Matt Bettencourt
Univ of Southern Mississippi
Stennis Space Center, MS

SLE-2
Near-shore & Estuarine Environments
STWAVE wave model, ADCIRC tidal circulation model, LSOM sediment model

Dr. Jane Smith
Engineer Research and Development Ctr
Vicksburg, MS

Dr. Cheryl Ann Blain
Naval Research Laboratory
Stennis Space Center, MS

Dr. Timothy Keen
Naval Research Laboratory
Stennis Space Center, MS

SLE-3
Surface Water/Ground Water, Riverine, and Tidal Environments
Surface Water/Ground Water RTE Models

Dr. Stacy Howington
Engineer Research and Development Ctr
Vicksburg, MS

Dr. Charlie Berger
Engineer Research and Development Ctr
Vicksburg, MS

SLE-4
System Applications
WAM, SWAN wave model coupling
Enviornmental Data Server (OASES)

Mr. Richard Allard
Naval Research Laboratory
Stennis Space Center, MS

Mr. Christopher Scannel
Naval Research Laboratory
Washington, D.C.

CTA LEADERS: Dr. Bill Burnett (CWO)

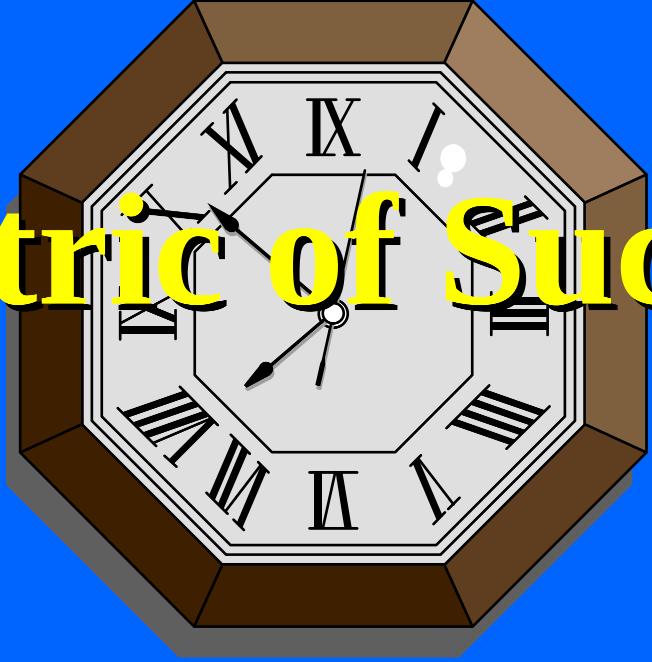
Dr. Jeff Holland (EQM)

Description of Portfolio

- This portfolio couples technologies that model the following key phenomena governing the complex littoral environment
  - Large-scale, remote oceanographic/atmospheric forcing
  - Topographically controlled mesoscale atmospheric phenomena
  - Bathymetrically controlled and locally forced ocean current, temperature and salinity structure
  - Near-shore surface waves and surf
  - River, stream & estuarine flow
  - Sediment transport
  - Interconnections between these phenomena

  to provide DoD with a capability to exploit littoral battlespace environments.

Metric of Success



For Real Time Nowcasting and Prediction Elapsed Wall Clock Time is by Far the Most Important Metric of Performance

&

the System as a Whole is Only as Fast as Its Slowest Component

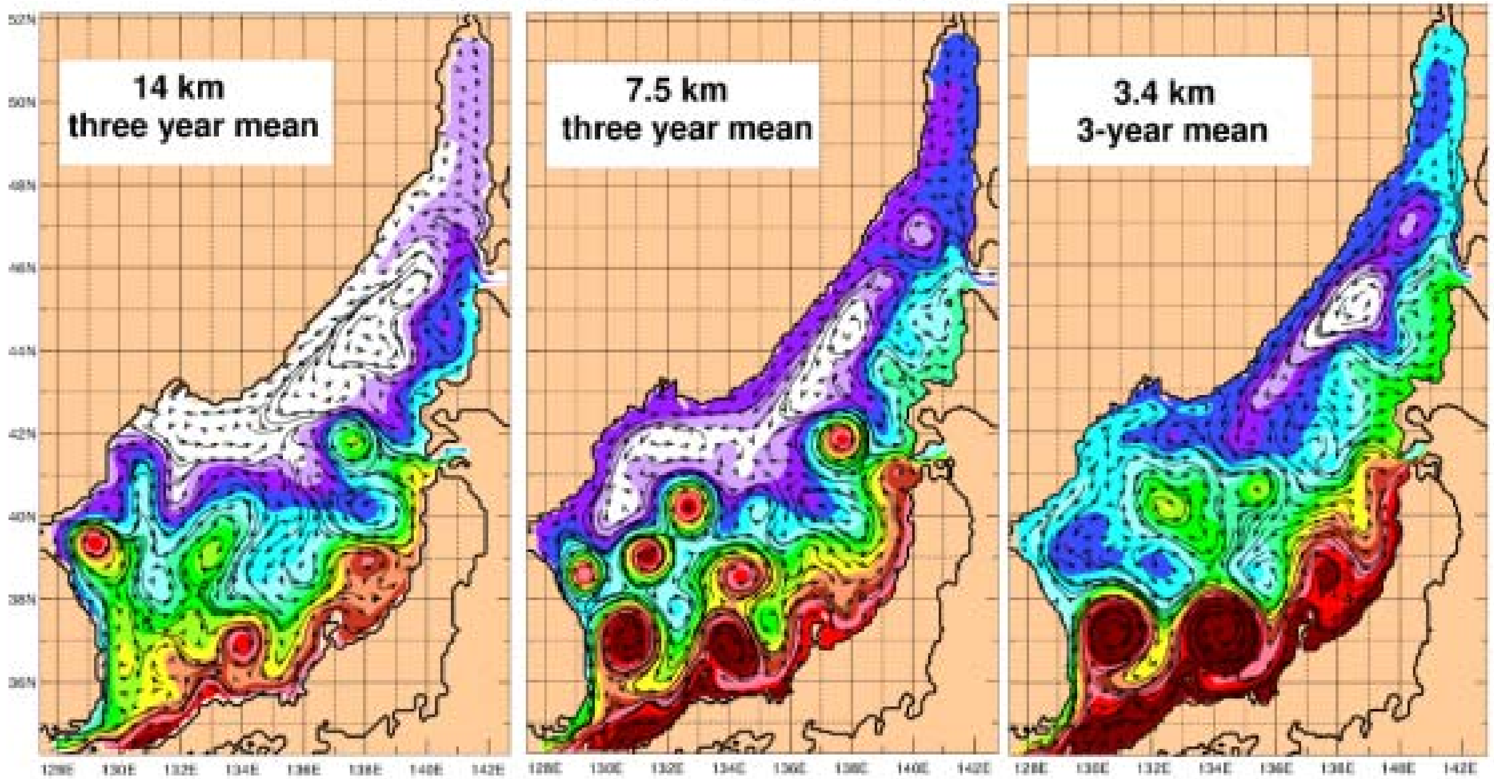
TIME to SOLUTION !!!!!

Hybrid Coordinate Ocean Model (HYCOM)

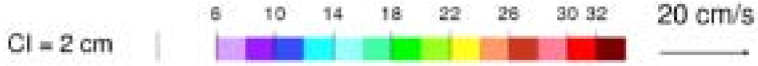
- Previous Paper (C79)--HYCOM
- Next-generation circulation model under development at NRL-SSC.
- Traditional ocean models use a single coordinate type to represent the vertical, but no single approach is optimal for the global ocean.
- Isopycnal coordinates (density tracking) are best for deep ocean.
- Z-levels (constant fixed depths) are best near the surface.
- Sigma-levels (terrain-following) are best in coastal domains.
- Japan/East Sea simulation: 394x618x15, one-year simulation requires 12,000 CPU hours per year.

JES HYCOM - Impact of Horizontal Grid Resolution

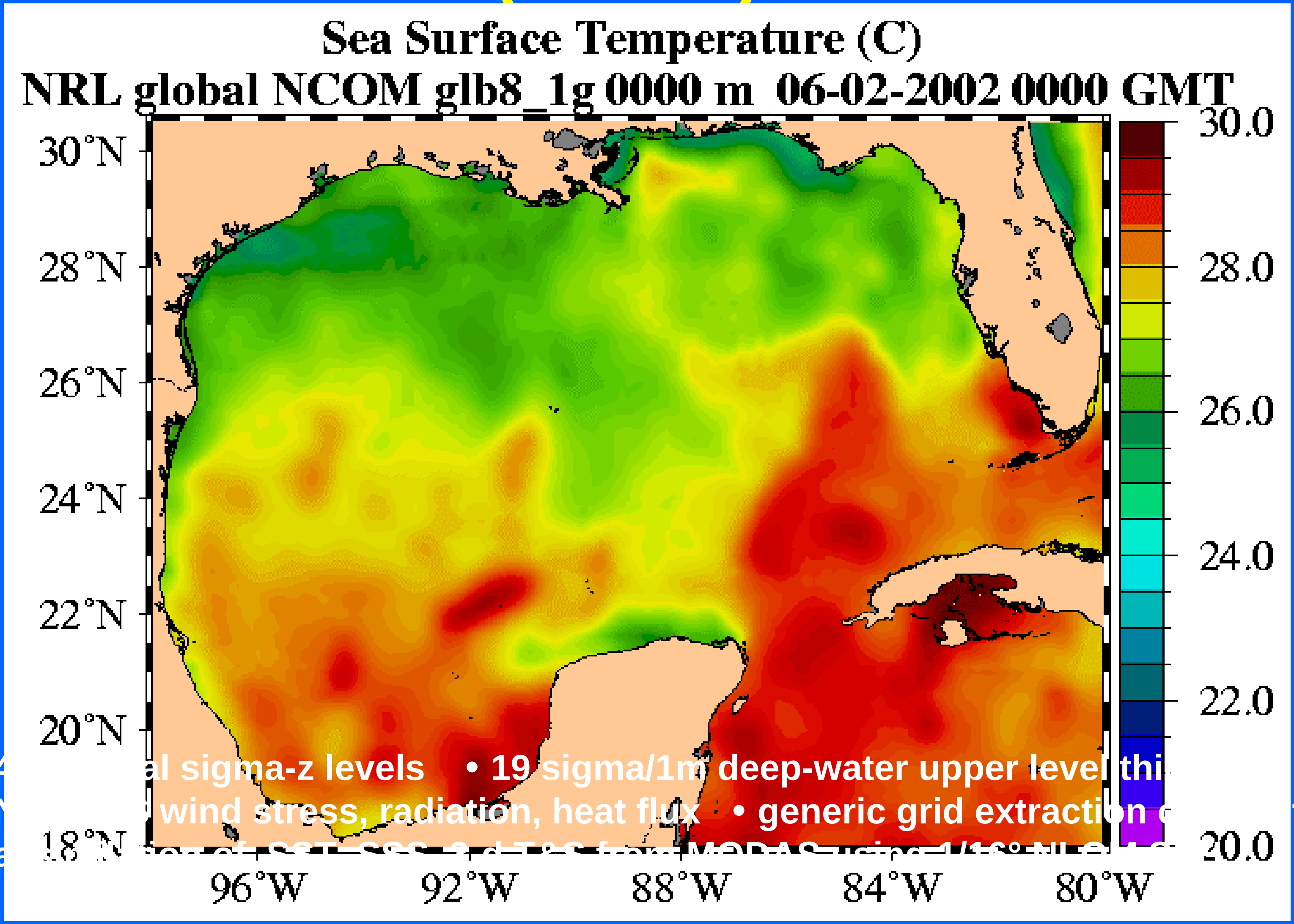
Free Surface deviation and surface layer currents



Forced by inflow/outflow through the straits and ECMWF 10 m atmospheric forcing (monthly + 6 hrly variab.)



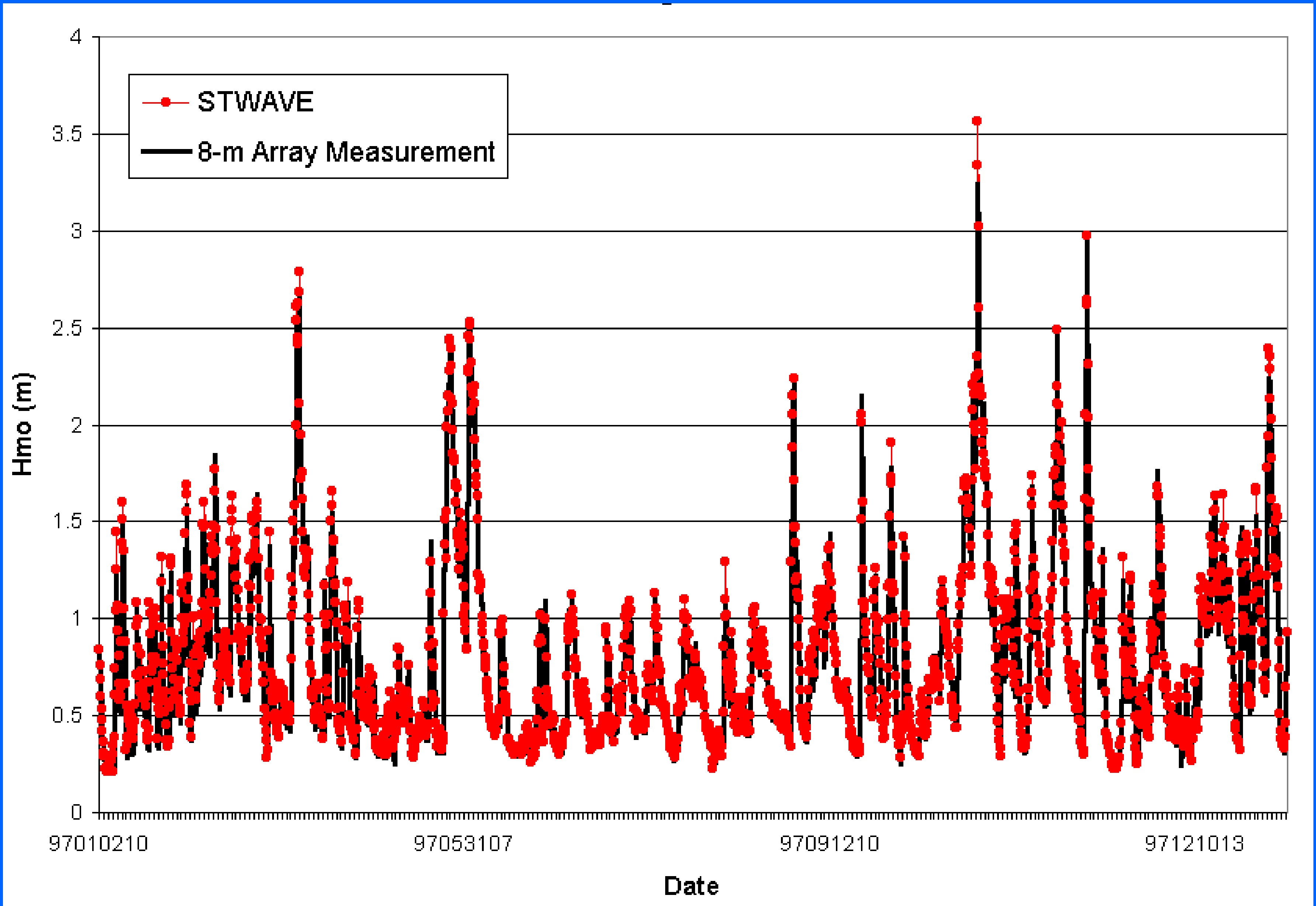
1/8° Global Navy Coastal Ocean Model (NCOM)



- 4 … al sigma-z levels • 19 sigma/1m deep-water upper level thi…
- N … wind stress, radiation, heat flux • generic grid extraction c… ty

STWAVE Overview

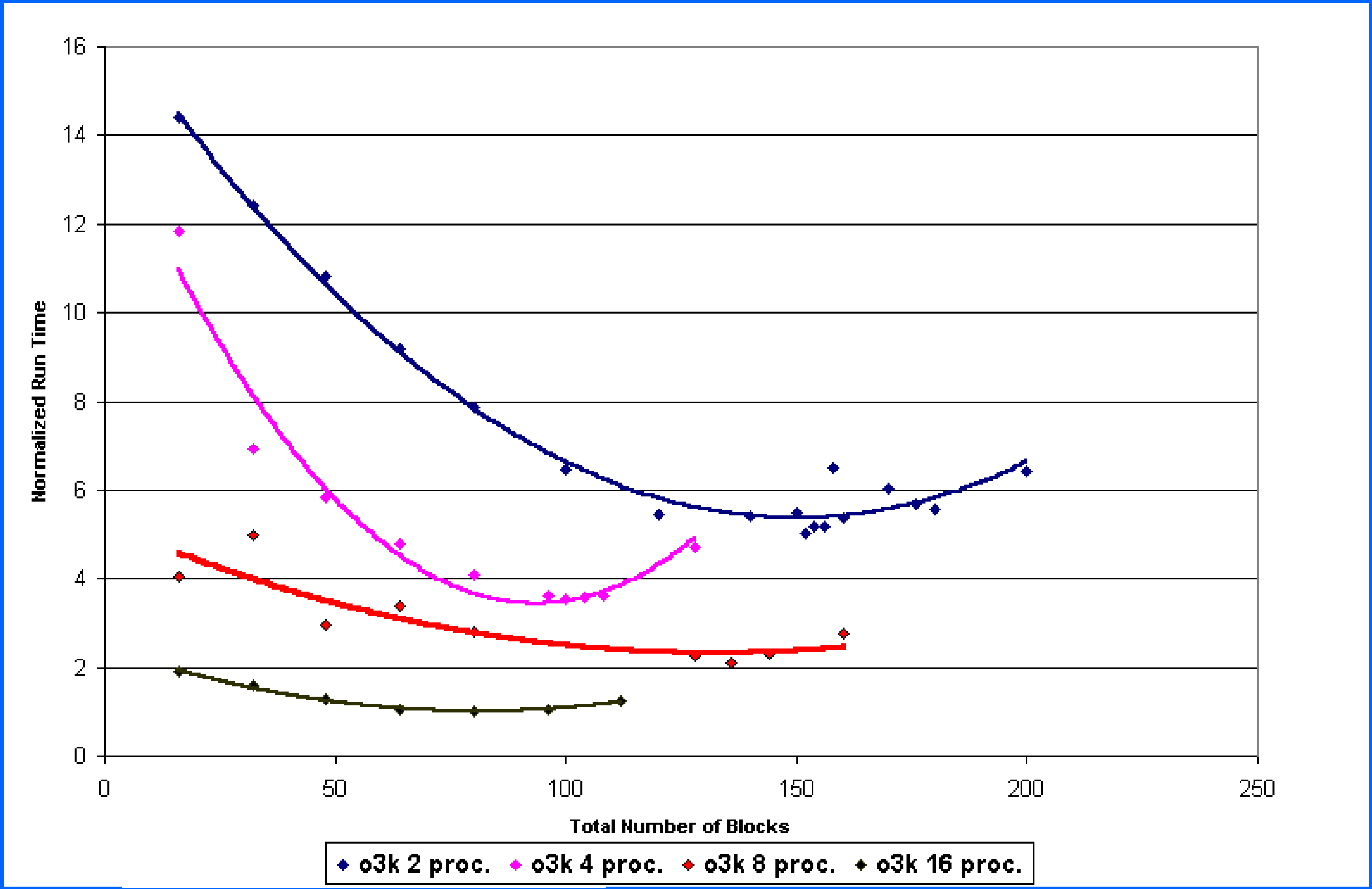
- Refraction & shoaling
- Wave-current interaction
- Diffraction (simple)
- Wave growth and white capping
- Depth- and steepness-induced breaking
- Dual-level MPI and OpenMP


STWAVE
8-m Array Measurement
Hmo (m)
4
3.5
3
2.5
2
1.5
1
0.5
0
97010210
97053107
97091210
97121013
Date

Adaptive Hydraulics Code (ADH)

- ADH code addresses a host of water related problems including resource protection and flow and constituent transport.
- Finite element model, uses MPI protocol for message passing among processors.
- Riverine and Tidal Environments (RTE) enhanced by developing a hydrostatic component to reproduce rivers and tidal circulation.
- Surface Water/Ground Water (SW/GW) improved to extend its applicability to larger basins and longer simulation periods.

SLE-3 Riverine and Tidal Environments



SWAN -- Simulating WAves Nearshore

- State-of-the-art wave model which computes realistic estimates of wave parameters in coastal regions, lakes and estuaries from given wind, bottom, and current conditions
- Based on wave action balance equation:
  - Wave action density spectrum: $N\,(x,y,\sigma,\theta;t)$
  - Source and sink terms $S\,(\sigma,\theta)$

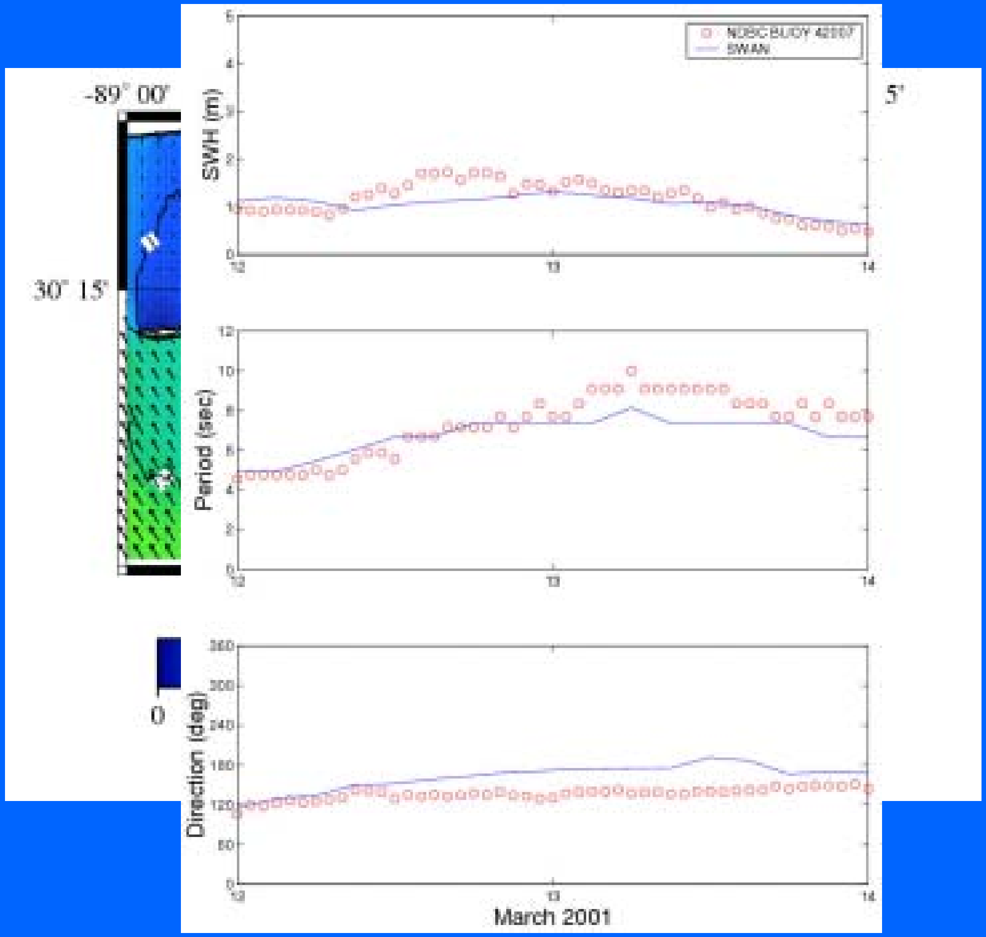
$$\frac{\partial}{\partial t}N+\frac{\partial}{\partial x}c_xN+\frac{\partial}{\partial y}c_yN+\frac{\partial}{\partial \sigma}c_\sigma N+\frac{\partial}{\partial \theta}c_\theta N=\frac{S}{\sigma}$$

- Can be run in non-stationary (time dependent), stationary modes
- Supports Cartesian, Curvilinear, Spherical coordinates
- Nesting Option, RESTART capability
- Full plane (waves traveling from any direction)
- Parallelized in OpenMP by NAVO PET (Campbell and Cazes)
  - (Wednesday, 1:30 PM paper)

OpenMP SWAN

- A shared memory pipelined parallel version of SWAN has been implemented using OpenMP
- Parallel version is “bit-for-bit” compatible with the original serial version
- No change to user interface
- Modifications have been accepted for next official release of SWAN
- Parallel version will be transitioned into operational use at NAVOCEANO

SWAN Studies in Mississippi Sound

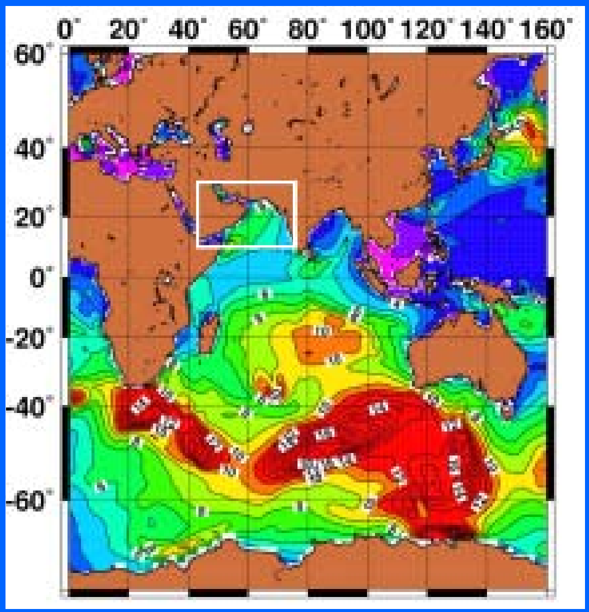


- Directional wave spectra from Regional WAM applied on model boundaries.
- Forced with COAMPS winds.
- 752x392 array (100m resolution)
- NAVO bathymetry from NGLI program
- Simulation March 12-14, 2001
- Buoy data from NDBC 42007, MS1

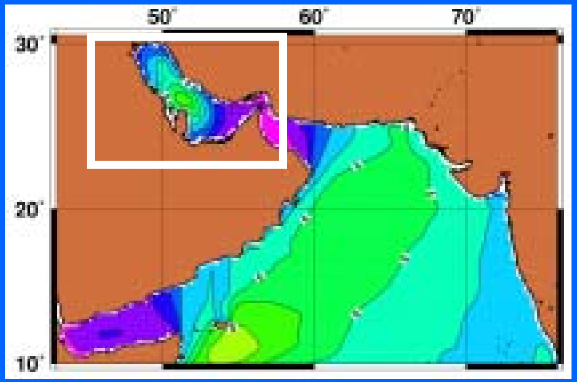
Persian Gulf Simulations

- Strait of Hormuz and Gulf of Oman is one of the busiest and most important shipping lanes in the world.
- A vessel passes through the Strait of Hormuz every 6 minutes.
- Approximately 60% of the world's marine transport of oil comes from this region.
- Models: ADCIRC, SWAN, LSOM

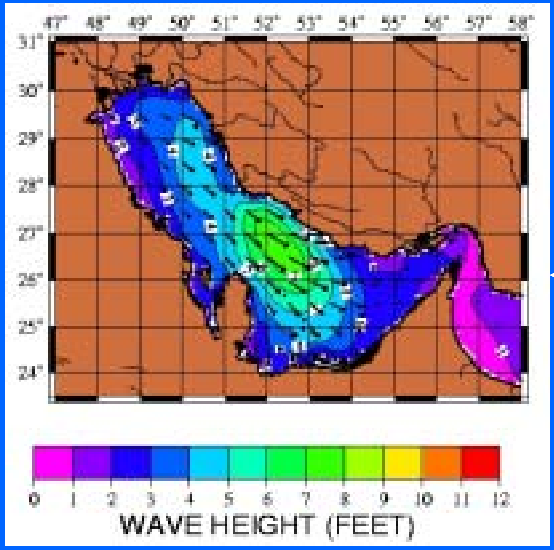
Persian Gulf Simulations



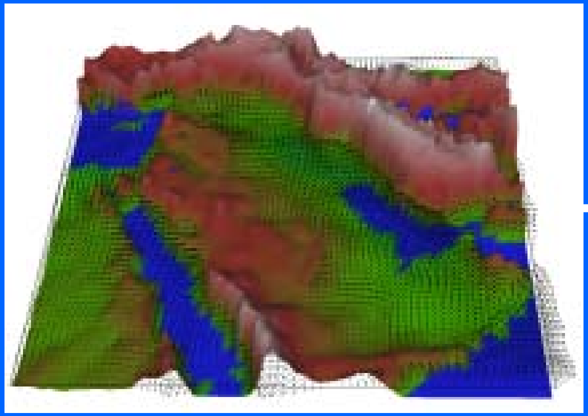
Basin-scale OpenMP WAM (1 deg resolution)



Regional WAM (0.25 deg res.)

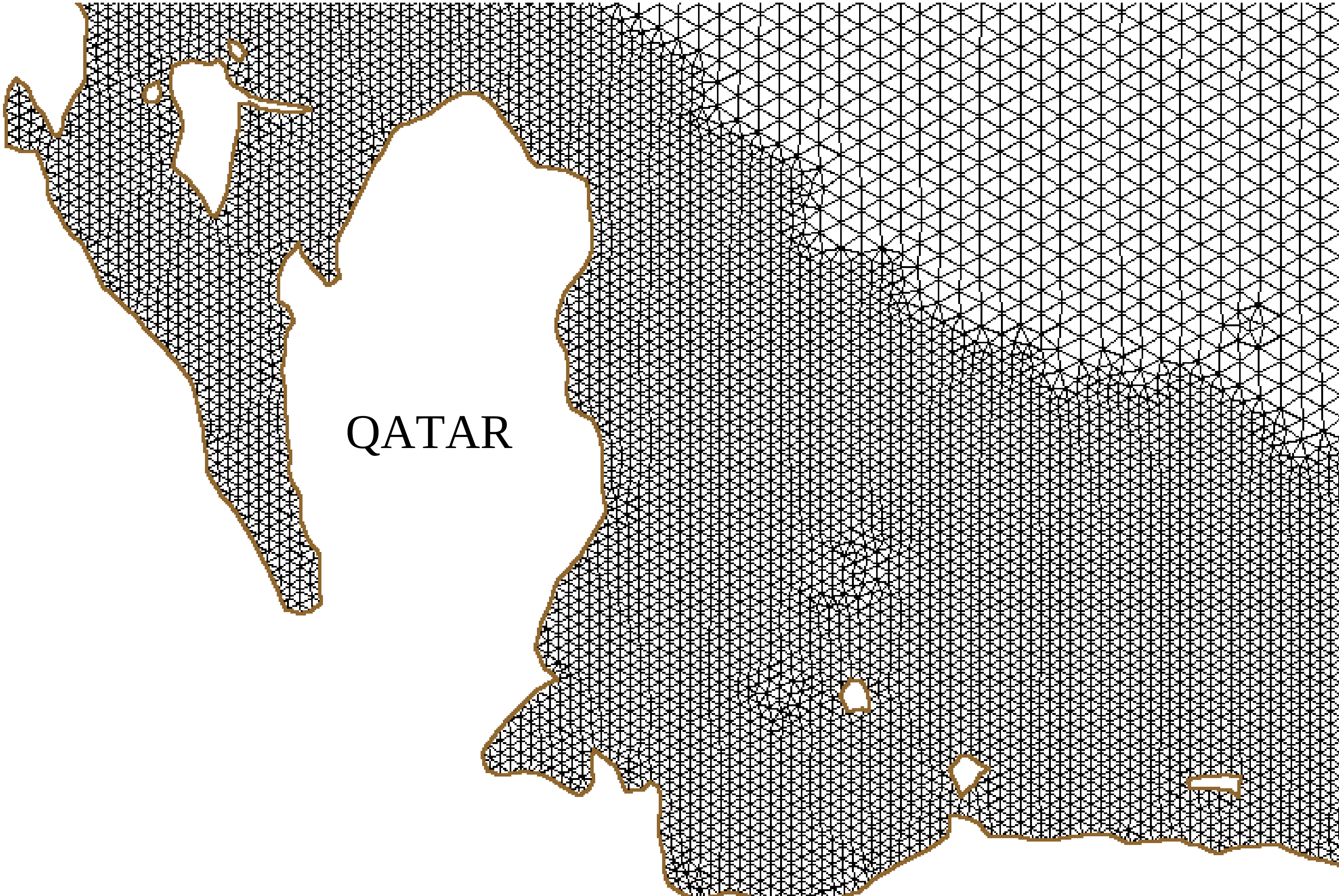


OpenMP SWAN (0.1 deg res.)



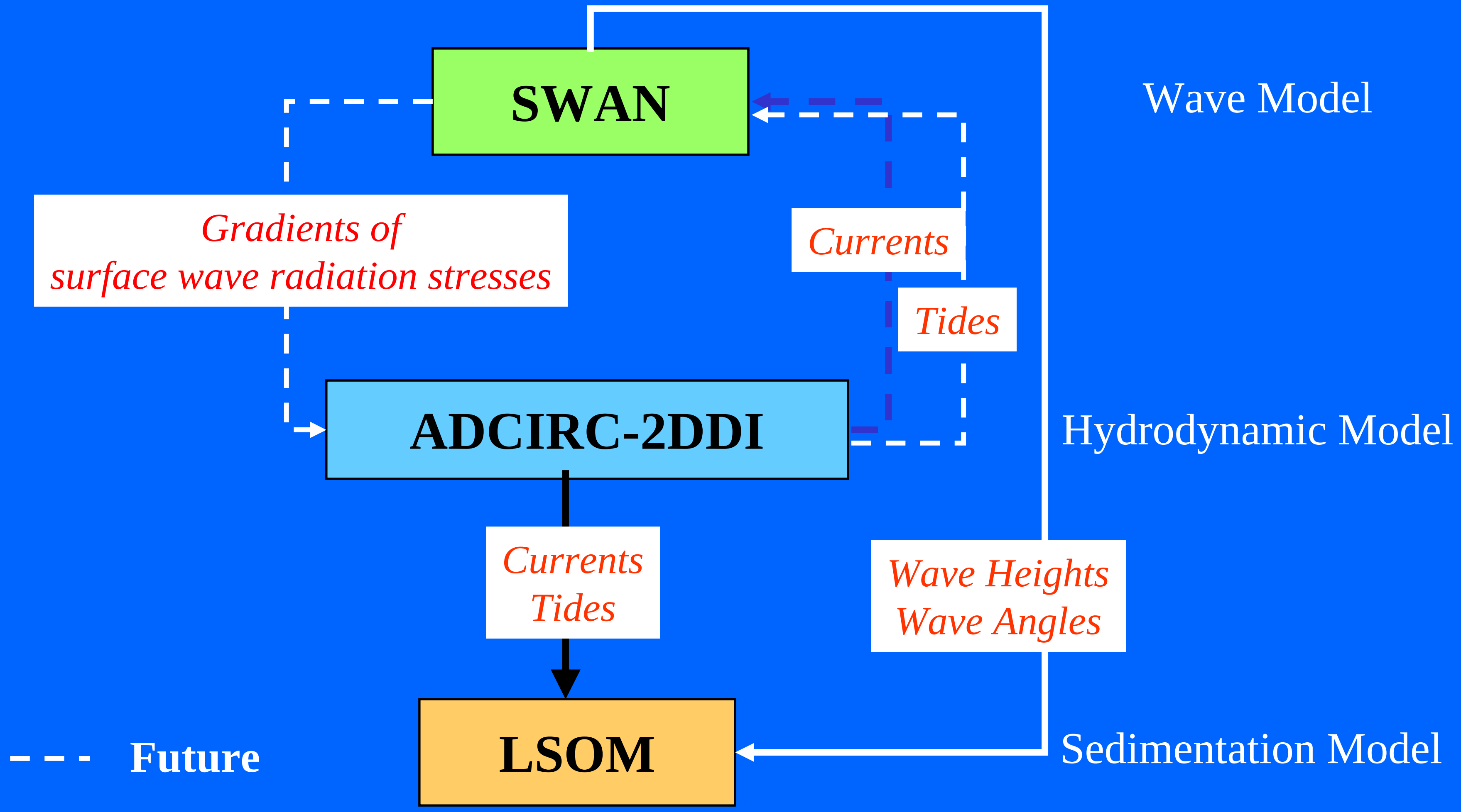
COAMPS wind forcing

ADCIRC PERSIAN GULF APPLICATION



MODEL COUPLING

CURRENT COUPLING SCHEMATIC



Littoral Sedimentation and Optics Model (LSOM)

- Derivative of TRANS98 model (Keen and Glenn, 1998)
- Bottom boundary layer component calculates the combined shear stresses resulting from wave and current interaction in the marine bottom boundary layer.
- Includes resuspension and optical properties of sand and silt.
- Inputs include: waves, currents, bathymetry and sediment type.

LSOM Diver Visibility

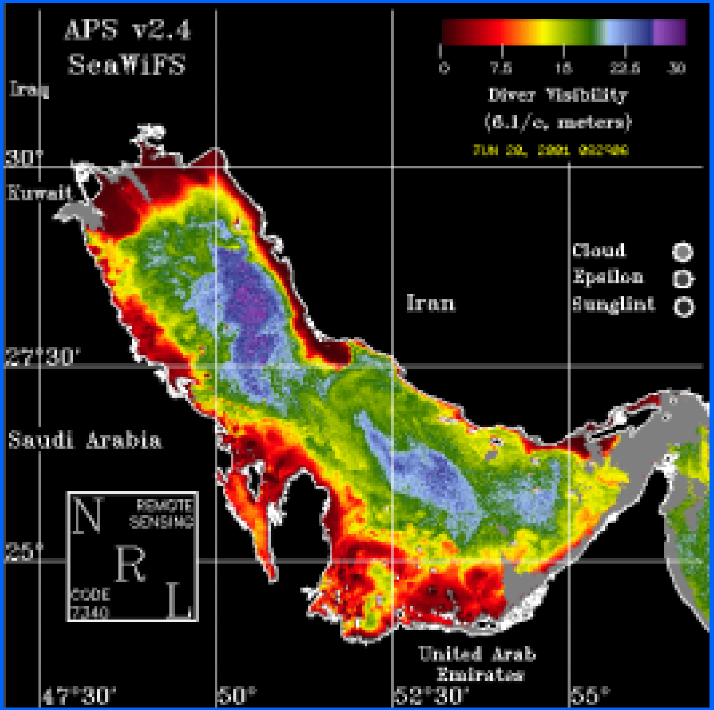
$$DV = \frac{4.8}{(b_{chlor} + b_{\mathrm{min}ero})} \times \frac{A_s}{0.3048}$$

b_{chlor} = scattering due to chlorophyll, based on chlorophyll calculated from surface chlorophyll concentration derived from SeaWiFs sensor

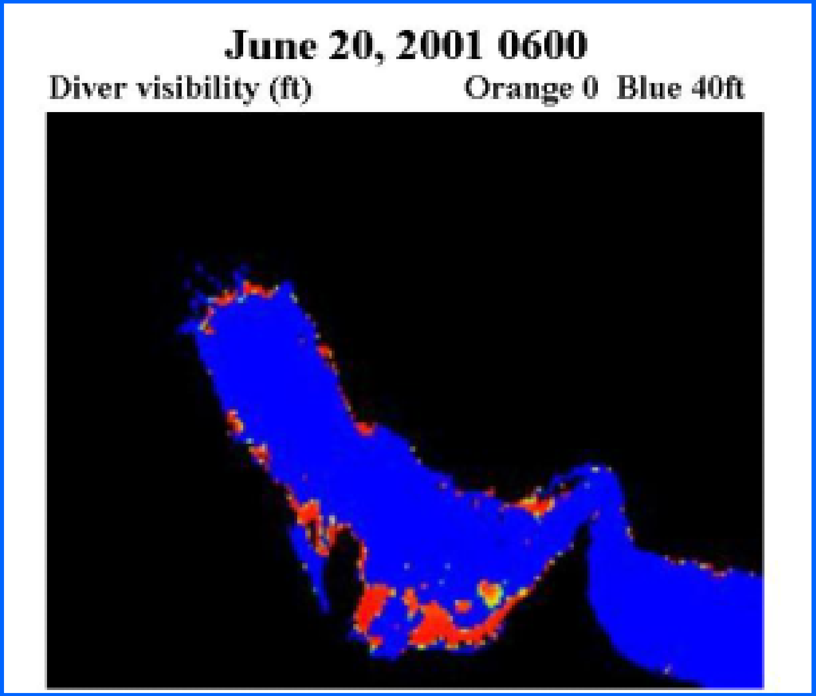
$b_{\mathrm{min}ero}$ = scattering due to resuspended mineral sediments

A_s = scattering albedo

Diver Visibility



SeaWiFS Diver Visibility
June 20, 2001

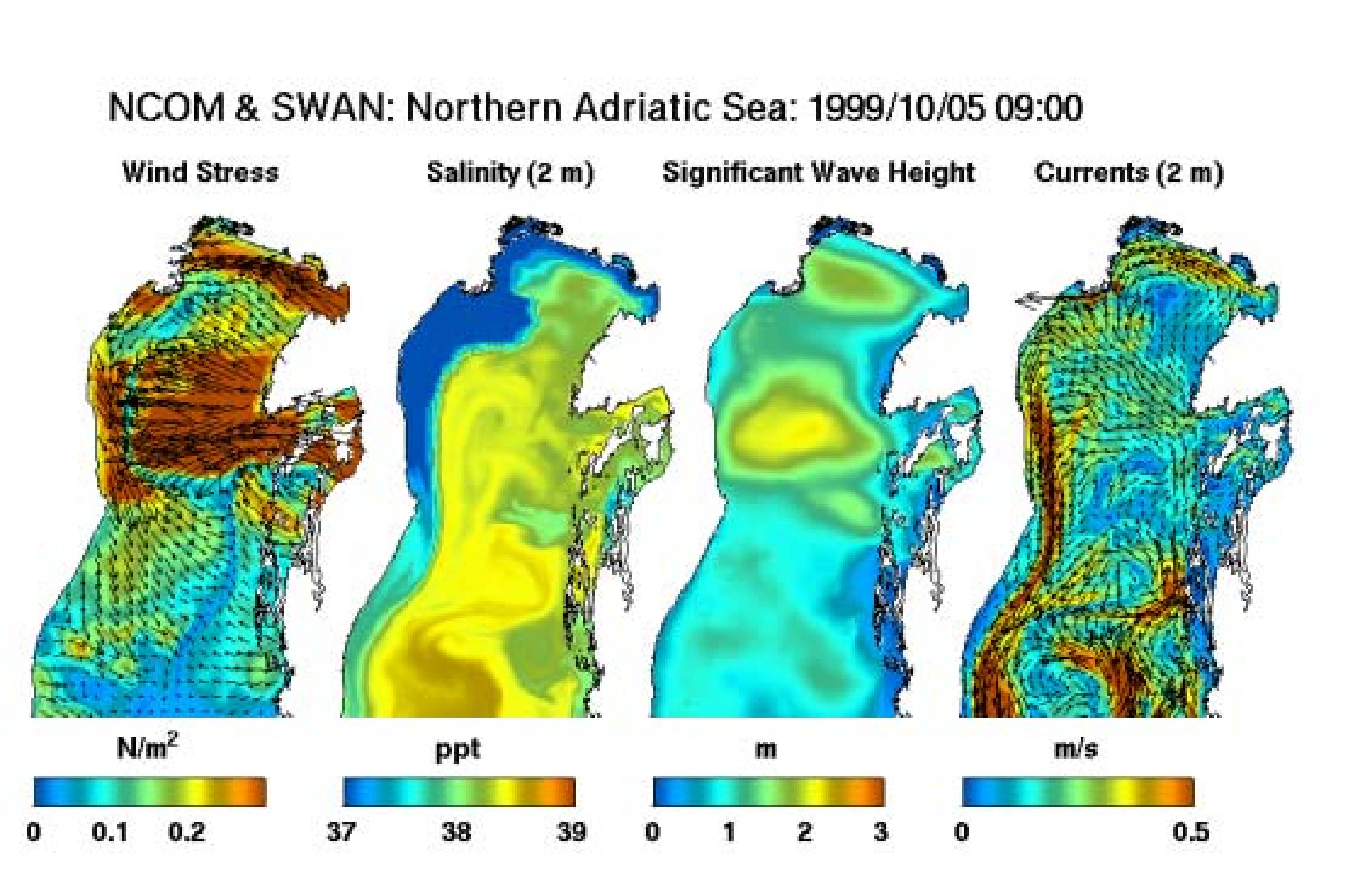


LSOM Result

Adriatic Simulations

- Wind provided by triple-nested COAMPS, with a 4 km resolution over the entire Adriatic. **(Challenge 379)**
- NCOM run for Adriatic at 2 km resolution, forced with COAMPS. **(Challenge 379)**
- SWAN run on same 2 km grid as NCOM.
- LSOM will be driven with currents and waves from NCOM & SWAN to provide simulations of sediment-related optical clarity for diver visibility and lidar penetration.
- Models will be critically assessed during large field program in the Adriatic (Sep 2002-May 2003)

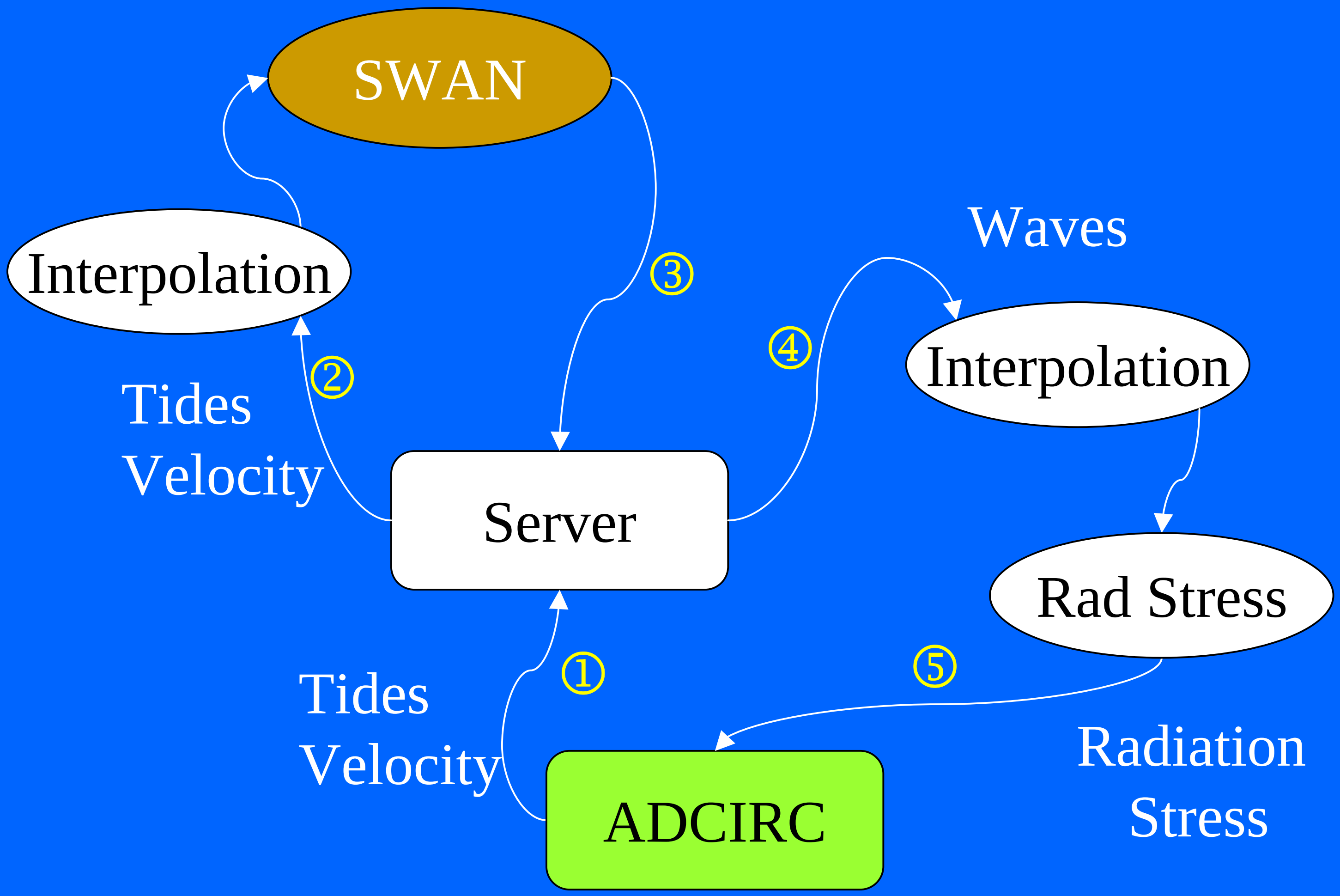
Adriatic Studies with COAMPS, NCOM & SWAN



Model Coupling Environmental Library (MCEL)

- Utilizes a data flow approach where coupling information is stored in a single server or multiple centralized servers.
- Communication between objects is handled by the Common Object Request Broker Architecture (CORBA).
- The extraction of the processes unique to model coupling into independent filters allows for code reuse for many models.
- MCEL-related papers:
  - **1:30 Today** (de Witt Room) “Distributed Model Coupling Framework” Matt Bettencourt
  - **4:30 Today** (de Witt Room) “The Development of a Coupled COAMPS-Wavewatch Modeling System Using MCEL” Pat Fitzpatrick

MCEL ADCIRC – SWAN



Future Plans

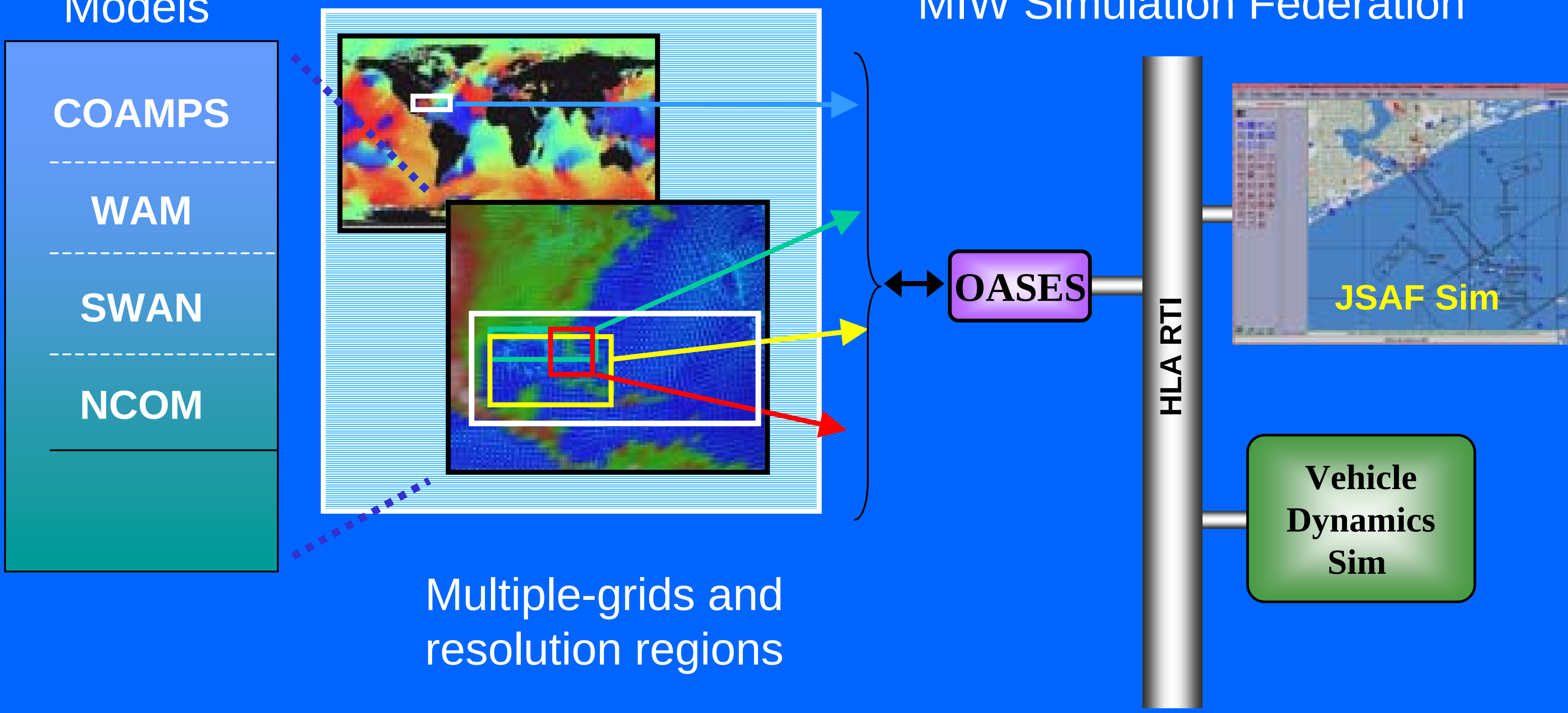
- Implement MCEL coupling series of models:
  - LSOM, SWAN, ADCIRC (Persian Gulf)
  - NCOM, SWAN, LSOM (Adriatic)
  - ADH, NCOM, ADCIRC (Mississippi Sound)
- Measure performance (scalability) and accuracy.
- Modeling & Simulation Server

SLE-4 Ocean Atmosphere Space Environmental Server

SNE Model Distributed Simulation Demonstration Architecture

SNE HPC Execution Models

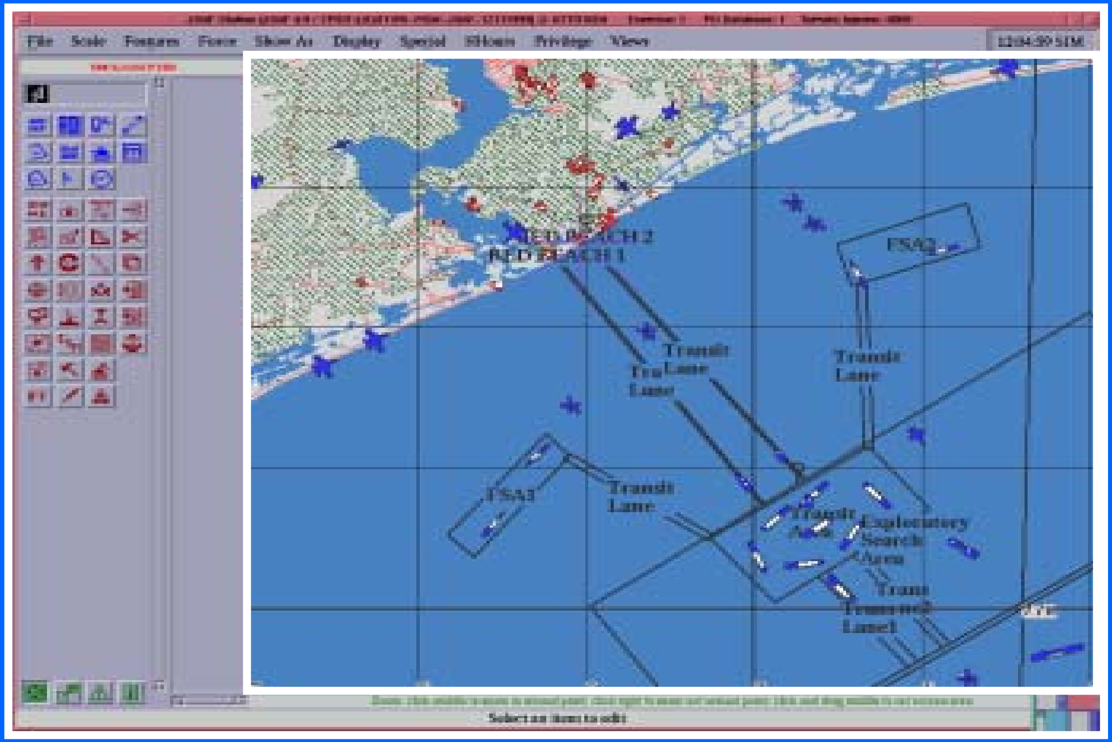
MIW Simulation Federation



Multiple-grids and resolution regions

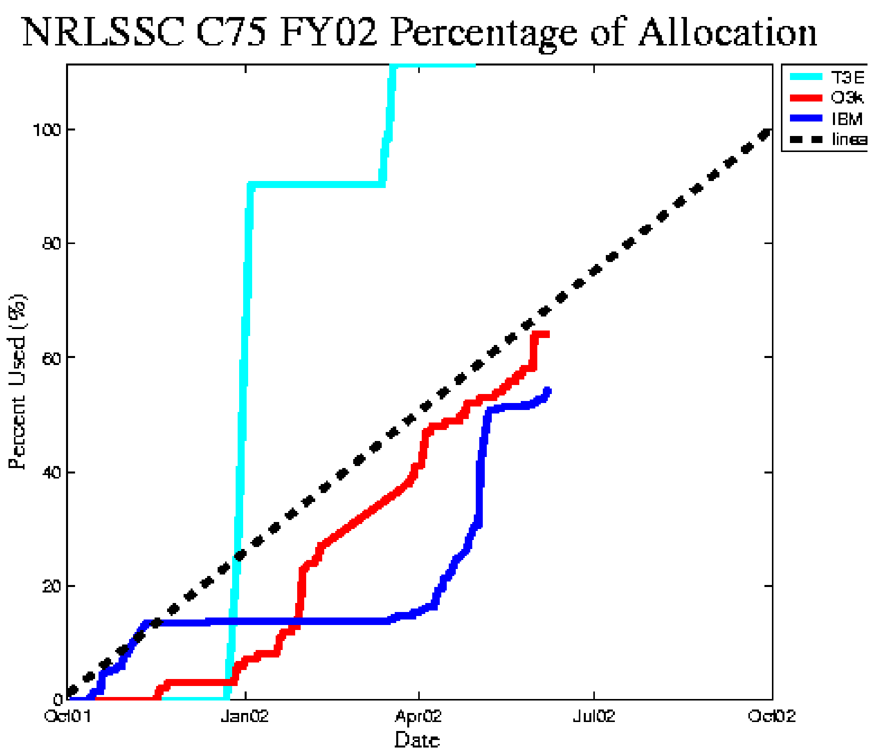
Simulation entities react to SNE

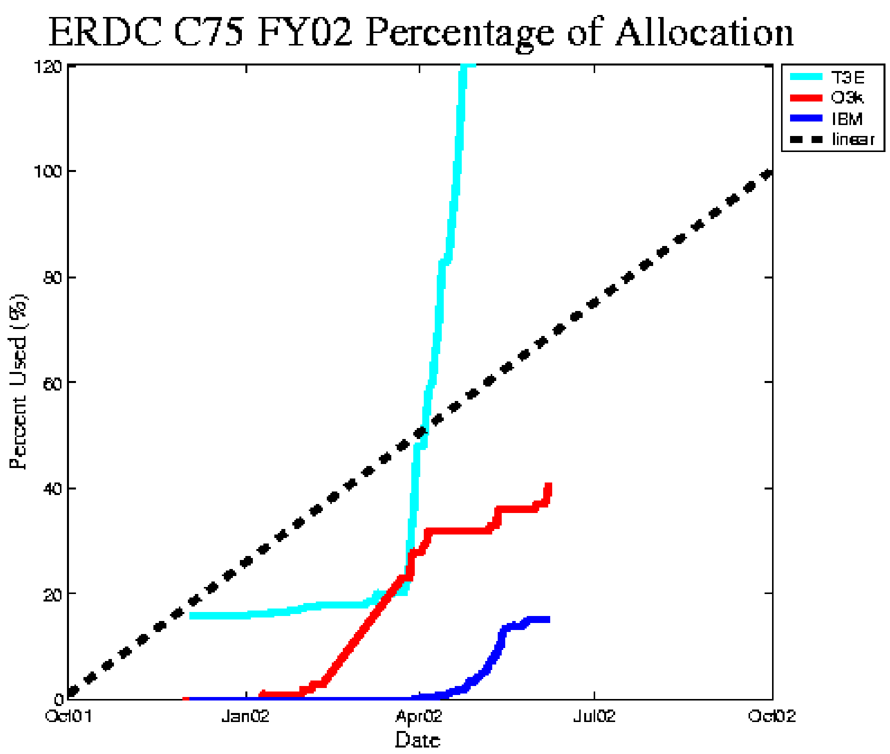
JSAF



Joint Semi-Automated Forces (JSAF) is a combat simulation which models the physical characteristics and behaviors of vehicles, weapon systems and sensors operating in the Synthetic Natural Environment.

NRLSSC75 and ERDCVC75 Usage (as of 7 June)





Special Thanks

- Margo Frommeyer
- Rick Gould (NRL) for SeaWifs image
- Tim Campbell, John Cazes (PET)